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TITLE: A NEW ERA FOR ULTRASONIC IMPACT GRINDING

MASTER

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A NEW ERA FOR ULTRASONIC IMPACT GRINDING

by

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ABSTRACT

New piezoelectric efficiencies allow impact grinding to progress up to 900 watts and above. This previously little known machining method takes on new importance in cutting and contouring extremely hard refractories and refractory metals such as boron carbide.

Introduction

History

As long ago as 1914 the Russians were studying ultrasonics. It was only as recent as 1945 that the first patent was taken out on ultrasonic impact grinding in England.

We have had ultrasonics involved in:

1. Nondestructive testing
    a. Thickness or crossection
    b. Crack
    c. Weld
2. Sonar (in water and air)
    a. Angle
    b. Distance

3. Ultrasonic welding
    a. Metal
    b. Plastic
4. Ultrasonic soldering
5. Ultrasonic cleaning

Now, ultrasonic impact grinding as a method of material removal is in its infancy.

Operating Principle

The actual material removal function (see viewgraph #1) is impacting the boron carbide grit into the work piece at a frequency and amplitude sufficient to remove material. The grit is carried by a fluid, usually water, which also keeps cutting temperature down. The material removed by the grit is carried away by the slurry solution.

Basic work is accomplished by high frequency, low amplitude, axial reciprocation motion of a tool shaped in reverse of the form desired.

Using the Branson ultrasonic system as typical, we have 20,000 Hz with an amplitude of .0004" to .002" and the energy to move tools as big as a 4" diameter with 900 watts.

The tool is fastened to a tool holder (or horn) attached to an amplitude booster which is attached to the driver (see viewgraph #2). The booster and horn are chosen to match the tool size and weight so that the driver frequency can remain near 20,000 Hz.

Applications

General

This system will machine any known hardness material less than a diamond, but is only competitive in specific applications. Think of it as an Electro Discharge Machine (EDM) without the necessity of conductive materials. It

effectively forms contours in materials that are so hard that they require diamond grinding, but it does have size and shape advantages over the cylinders and flats made by diamond grinding.

Most applications we have had so far are in the areas of quartz, glass, ceramics, and hard refractor metals.

We are beginning to get actual production work now and thus we will have an opportunity to find new applications and challenges.

Feed Rates

At this point most of our work has been with boron carbides and we have developed some feed rates as enumerated below. Please note that these rates are subject to improvement and already exceed those published. [1]

Table 1

Material	Theoretical Density	Gross Feed Rate (inches/minute/sq. inch of area) of Tool Face
Boron Carbide	94%	.0158
Boron Carbide	96%	.0055
Tungsten Alloy Boron Carbide	____	.0015

Although these feed rates are not impressive, please keep in mind that this material is at least 50% harder than tungsten carbide. It is off of the Rockwell "A" scale. The boron carbide has a Knoop hardness of 2800. It is easy to understand why other relatively soft materials will show much higher removal rates.

Problems and Solutions

Tuning

Because of the 20,000 Hz vibrations, the horn and tool must also have a natural vibration rate to match. At the present time it is necessary for the factory to tune your tooling to a horn.

Solution - We have had the factory tune our various horns to given weights so that if we make our tool to that given weight we will have a tuned combination. This works quite well as long as the tool length does not vary too much.

Also, we have developed a centroid balancing method which has allowed us to balance using length as a factor as well as weight.

Nevertheless, if in doubt or for optimized tuning conditions, we may still use the factory balance service (and check it against our method).

Tool Wear

This problem is directly related to time in the cut and is much worse in cutting the harder materials. In tungsten alloy boron carbide, tool wear has been as much as 44% of the tool feed. On softer materials the tool is fed quicker and becomes much less critical.

Solution - As we develop better and more efficient feed systems with improved cutting rates our tool loss will be reduced, but tool wear will always exist to some extent.

Grit Circulation

Initially our grit was falling out of suspension.

Solution - This problem was resolved with cavity modifications in the slurry bowl where the pump sits.

Grit Wear

Boron carbide grit will last a long time working in relatively soft material. It might last a year when used on quartz, low density ceramic, or glass. Boron

carbide grit has no life when working in a harder material like tungsten alloy boron carbide and should only be used on a total loss basis.

Other

Problems like rigid tool locating, better feed systems, and improved instructions are being solved as they come up by Rio Grande Jewelry, the Branson impact grinder dealers in Albuquerque, N. M. They have given us their fullest cooperation and are interested in helping with our unique problems.

Latest Developments

Weldpower, formerly Raytheon, and Branson have sold most of these machines. Branson's latest, the 900 watt, is the unit referred to in this report.

Older, magnetostrictive driver systems typically lost 30-40% of their efficiency to heat and must use some air or water cooling. The latest Branson systems use piezoelectric drivers which are over 90% efficient, use no outside cooling system, and can run 900 watts and greater.

We are doing work now on boron carbide and tungsten alloy boron carbide. The hardest, most dense material found thus far reduces it down to cutting rates like .0006"/min. per .100 in^2 area. This cut is in material much harder than tungsten carbide and in fact makes any ceramic easy cutting by comparison.

We are developing means of advancing the tool instead of loading it in a feed mode. The tool actually seems to prefer a constant clearance between itself and the work. This will increase feed rate and help reduce tool wear.

Future

Feed Rates

As time permits we plan to upgrade our tooling by making tooling material changes in an attempt to improve feed rate. Right now a tougher tool cuts a harder material more efficiently. We have tried 303, 304, and 440C stainless tooling so far.

Amplitude experiments will be conducted to find the best combination of amplitude and grit size for the fastest cutting of particular grain or crystal sizes.

A combination of tool pressure and gap relationship needs further study to optimize material removal.

Accuracy

A further study of the relationship between final part size and tool size is needed. Work thus far indicates .001" clearance is about right but it varies with material, depth, etc.

Finish

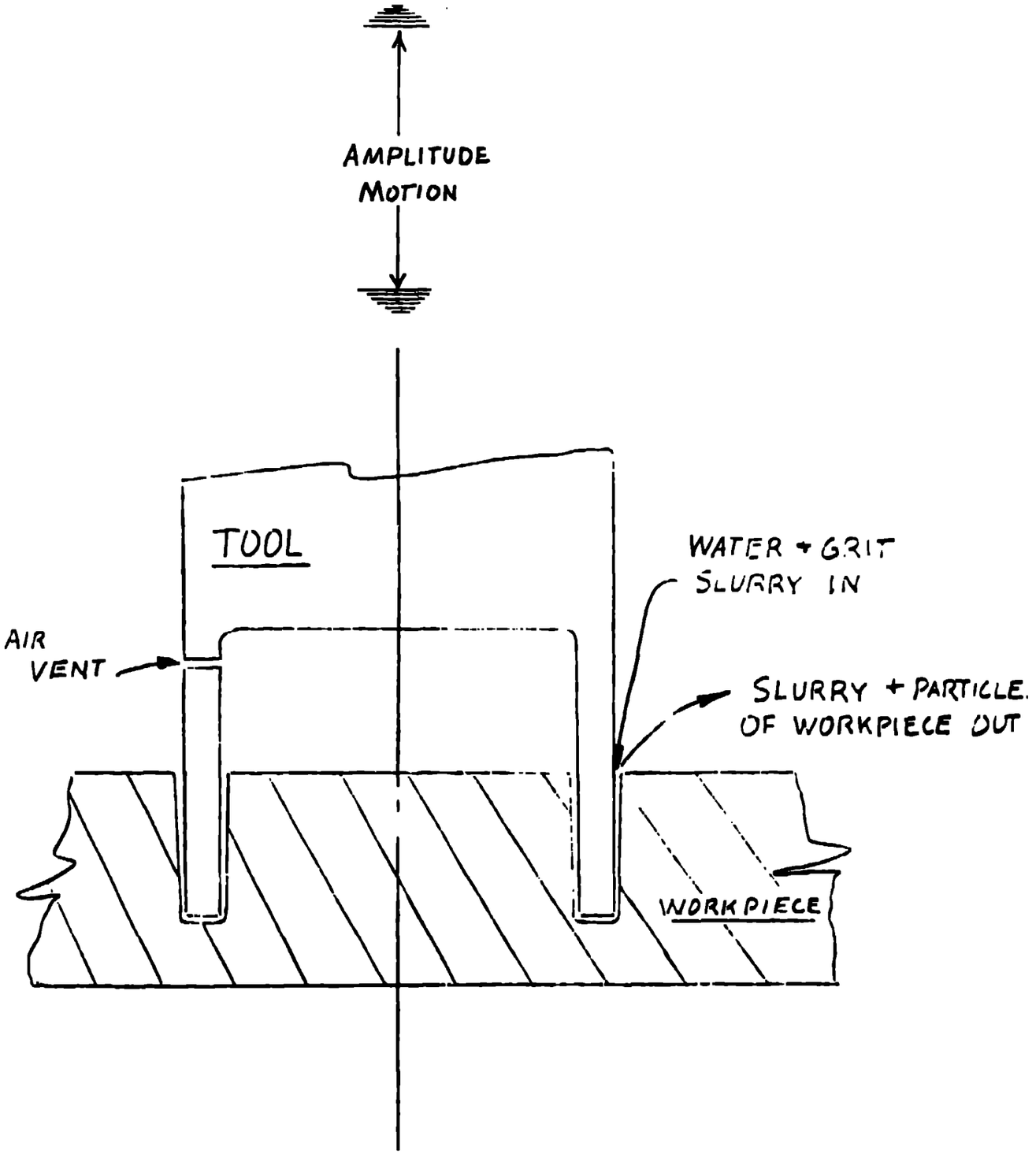
We may need to know what finish we can accomplish using variables of material, grit size, amplitude, etc.

General

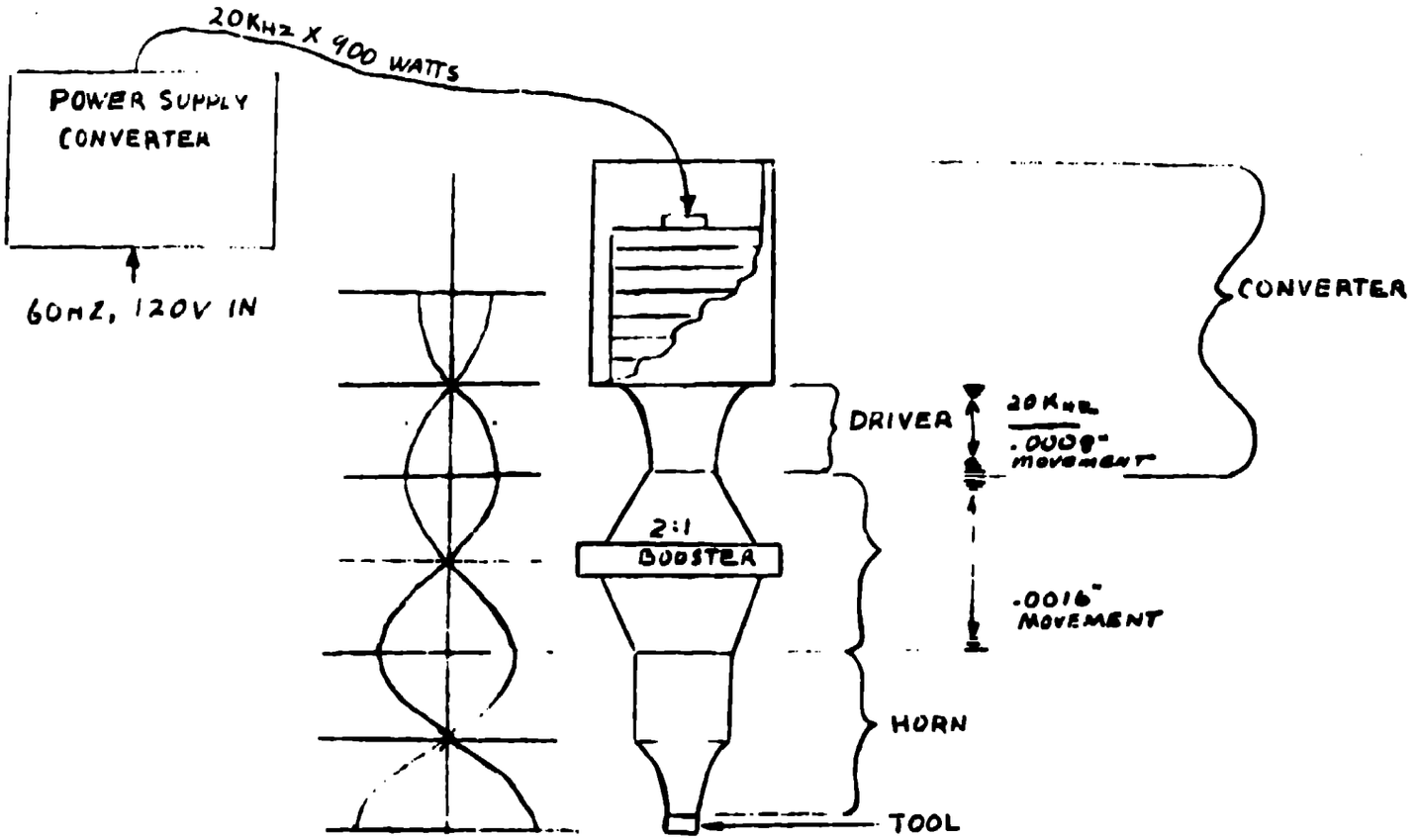
It is impossible to predict the characteristics of unseen jobs, but this process will become more important as more hard or nonconductive materials are needed.

References

1. R. K. Springborn, "Non-Traditional Machining Processes," ASTME 2:33, 1967.


AMPLITUDE
MOTION
TOOL
WATER + GRIT
SLURRY IN
AIR
VENT
SLURRY + PARTICLE
OF WORKPIECE OUT
WORKPIECE

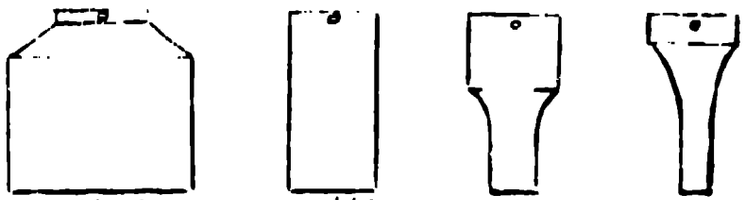
VIEWGRAPH - 1



AVAILIABLE BOOSTERS - AMPLIFICATION

BLUE	½
GREEN	1
GOLD	1½
SILVER	2
BLACK	2½

HORN TYPES (BLANKS)



← AMPLITUDE INCREASE

BRANSON IMPACT GRINDER

VIEWGRAPH .7

2·80

Ultrasonic

impact grinding equipment

The 900 Watt Ultrasonic Impact Grinder pictured above incorporates the state of the art in ultrasonics as used to cut, drill and carve gems, stones, ceramic, crystal or glass.

- 900 WATTS POWER: Allows fast and efficient cutting with tools 4" (10 cm) diameter.
- ACCURATE TOOL POSITIONING AND DEPTH CONTROL: Permits semi-automatic operation; one operator can control several machines. Also ideal for close tolerance work.
- ADJUSTABLE AMPLITUDE: Insures rapid cutting speed regardless of grit size or material being cut.
- RECIRCULATING GRIT FEED SYSTEM: Applies ample grit to the cutting surface at all times.